

R. J. B. A. S. E.

The Association
of
Engineering and Shipbuilding
Draughtsmen.

HELICAL COIL
SPRINGS.

By T. HAYDN WHITEHOUSE and
H. P. CLARKE.

Published by The Association of Engineering and Shipbuilding Draughtsmen,
96 St. George's Square, London, S.W.1

**The Association
of
Engineering and Shipbuilding
Draughtsmen.**

**HELICAL COIL
SPRINGS.**

**By T. HAYDN WHITEHOUSE and
H. P. CLARKE.**

Published by The Association of Engineering and Shipbuilding Draughtsmen,
96 St. George's Square, London, S.W.1

HELICAL COIL SPRINGS.

By T. HAYDN WHITEHOUSE and H. P. CLARKE.

It is obvious that in mechanical designs involving the use of springs these must be considered first as their dimensional limitations will affect to a lesser or greater degree the final arrangement of the mechanism.

Anyone who has had to use springs in problems of this nature will appreciate the difficulties when faced by so many variables. The charts offer in an easily comparable form a complete range of practical helical coil compression and tension springs of up to 1" dia. wire and 12" mean coil diameter in a series of useful stages. Intermediate coil diameter can be obtained by interpolation if necessary. The range is limited to practical proportions by the spring index and Wahls' correction factor so that any spring not falling in the chartered range will not be generally acceptable as a practical component.

When a suitable spring has finally been selected from the charts as much information as possible should be forwarded to the manufacturer when enquiring or ordering. Typical drawing layouts showing a suitable way of doing this are given on sheet 4, and it is recommended that this standard method be adhered to in detailing springs.

Sheet 1 gives relevant formulae and notation as used throughout.

Sheet 2 gives the equivalent formulae for square and rectangular wire, together with information and factors to enable the inch plate and safe load charts to be used. The required inch rate can be read directly off the chart by taking an equivalent size of round wire as shown and multiplying by the appropriate factor as tabulated. The safe load figures are complicated by the fact that the allowable stress varies with the wire sizes on the chart and which is indicated in the various sections. The values upon which the charted figures are based are for hard drawn wire E.N. 49/B, C. & D, range 1 (minimum). Square and rectangular wire is hardened and tempered and the allowable stress will therefore differ. This is usually taken as being 40% of the ultimate tensile stress. In order therefore to obtain the correct safe load the equivalent value for round wire found in Chart II. must be multiplied by the factor found by dividing the stress to be used by the stress allowed on chart. This corrected figure can then be multiplied by the factor θ tabulated.

Sheet 3 gives notes regarding use of charts and a table of safe stresses for hard drawn wire to B.S. 1408/47. E.N. 49 B, C. & D.

HELICAL COIL SPRINGS

On Sheet 4, in addition to the drawing layouts already referred to, will be found a series of details showing the various ends that can be made on compression and extension springs. It should be noted that complete details of the types of ends required should be given to the manufacturers in order that no confusion over misleading terms will occur.

Sheet 5 contains the Inch Rate and Safe Load Charts Nos. I. and II. Chart I. is based on formula 1, sheet 1, and gives the complete range of springs between the spring index values of 3 and 15, 3 at the top. It is inadvisable to use springs with a lesser or greater index than this. The most serviceable size is that with an index of 9 and this series is indicated by the two centre zig-zag heavy lines. The outer pair of heavy lines indicates the series of springs with indexes of 6 to 12. It should be noted that the values given have been computed with $N = 1$ where N is the number of working coils. Therefore to obtain the inch rate for an existing spring, divide the figure given by the number of coils and to find the number of coils for a given rate, divide the figure by the rate required.

The safe load may be read off directly on Chart II. It is based on formula 2, sheet 1, using the values for S_s as quoted. These are taken from stress values given in B.S. 1408/47 and are the safe allowable stresses given under the minimum values for wire in Range 1, Sheet 3. Safe loads for the other values and ranges can be obtained by multiplying by the factors given on Sheet 3. E.N. 49B is specified as hard drawn patented wire (not for high duty). E.N. 49C is specified as high duty wire (unground). E.N. 49D is specified as high duty wire (ground). The term high duty is specified in B.S. 1408 as wire suitable for valve springs or other applications where it is essential to have the highest possible resistance to fatigue.

Sheet 6 contains the Initial Tension Chart III. which is based on formula 3, Sheet 1, and experimental data published in "Spring Design and Calculations" by John A. Roberts. This book deals very thoroughly with all aspects of spring design and is recommended to all interested in further study of this absorbing topic. We are indebted to Mr. John A. Roberts and Messrs. Herbert Terry & Sons, Ltd., for permission to use the relevant formulae and data. This initial load applies only to extension springs and is the load required to be exerted on the springs before the coils begin to open. When this state is reached the spring thereafter performs as would a compression spring, the inch rate given on Chart I. being the load required to extend the spring and not compress it. It should be noted that this initial tension only occurs with springs made from hard drawn wire as given by B.S. 1408, E.N. 49B, C. & D. Springs which are made with square wire or wire hardened and tempered after coiling have no initial tension and will begin to extend at the inch rate as soon as any load is applied.

HELICAL COIL SPRINGS

ROUND WIRE

FORMULAE:-

INCH RATE:-

1.
$$x = \frac{Gd^4}{64NR^3} \text{ lbs/inch} \quad (\text{SEE CHART I})$$

SAFE LOAD:-

2.
$$W_2 = .1964 \frac{S_2 d^3}{RK} \text{ lbs.} \quad (\text{SEE CHART II})$$

INITIAL TENSION LOAD:-
(EXTENSION SPRINGS)

3.
$$W_1 = .1964 \frac{S_1 d^3}{R} \text{ lbs.} \quad (\text{SEE CHART III})$$

WHERE

d = WIRE DIAMETER IN INCHES

N = NUMBER OF COILS

R = MEAN RADIUS OF COILS IN INCHES

G = MODULUS OF RIGIDITY

S_1 = INITIAL TENSION STRESS IN LBS/IN²

S_2 = SAFE FIBRE STRESS (SEE TABLE) IN LBS/IN²

C = SPRING INDEX = $\frac{2R}{d}$

K = WAHL'S CORRECTION FACTOR =

$$\frac{4C-1}{4C-4} + \frac{.615}{C}$$

HELICAL COIL SPRINGS

RECTANGULAR & SQUARE WIRE.

INCH RATE:- $\frac{\beta h^3 b G}{2 R^3 \pi N} = \frac{G D^4}{64 N R^3}$ (FOR ROUND WIRE) $\times \lambda$ lbs/inch

SAFE LOAD:- $\frac{S_2 \mu b h^2}{R K} = \frac{1964 S_1 d^3}{R K}$ (FOR ROUND WIRE) $\times \theta$ lbs.

WHERE b = LONGER SIDE AND h = SHORTER SIDE IRRESPECTIVE OF WHETHER THE SPRING IS MADE UP WITH THE BAR COILED EDGEWISE OR FLATWISE

NOTE:- S_2 Values allowed in CHART II are not necessarily correct for square wire. To obtain correct value, given figure must be multiplied by a factor obtained by dividing the stress to be allowed by the stress value given in CHART II. Allowable stress is taken as 40% of the Ultimate Tensile Stress.

TO FIND INCH RATE OR SAFE LOAD FROM CHART:-

Find Inch Rate or Safe Load of similar round wire spring taking d for Inch Rate as $\frac{4}{b \times h^3}$ and d for safe load as $\frac{3}{b \times h^2}$. The values found must then be multiplied by λ (Inch Rate) or θ (Safe Load) as given by $\frac{b}{h}$ in the following table.

TABLE OF VALUES FOR μ, β, λ & θ FOR SQUARE WIRE.												
$\frac{b}{h}$	1	1.5	1.75	2.0	2.5	3.0	4.0	6.0	8.0	10	α	
μ	.208	.231	.239	.246	.258	.267	.282	.299	.307	.313	.333	
log	7.3181	7.3636	7.3784	7.3909	7.4116	7.4265	7.4502	7.4757	7.4871	7.4955	7.5224	
β	.141	.196	.214	.229	.249	.263	.281	.299	.307	.313	.333	
log	7.1492	7.2923	7.3304	7.3598	7.3962	7.4200	7.4487	7.4757	7.4871	7.4955	7.5224	
λ	1.436	1.996	2.179	2.332	2.536	2.679	2.862	3.045	3.126	3.187	3.390	
log	.1571	.3002	.3383	.3677	.4041	.4279	.4566	.4836	.4950	.5034	.5303	
θ	1.059	1.176	1.217	1.252	1.313	1.359	1.432	1.523	1.563	1.593	1.695	
log	.0249	.0704	.0852	.0977	.1184	.1333	.1560	.1825	.1939	.2023	.2292	

HELICAL COIL SPRINGS

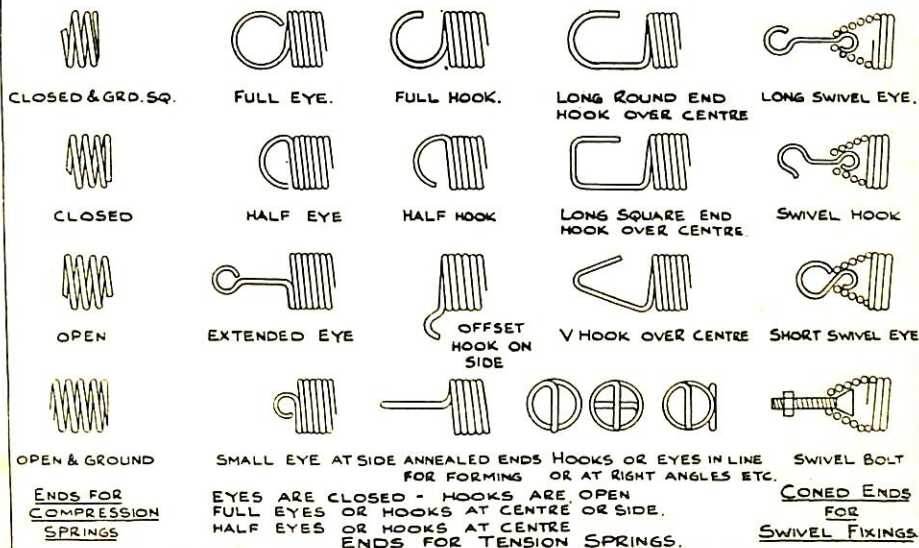
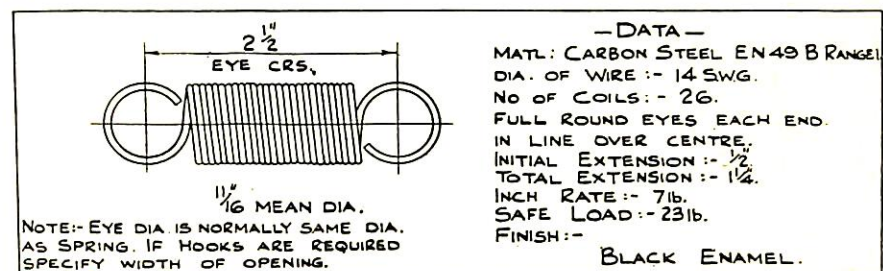
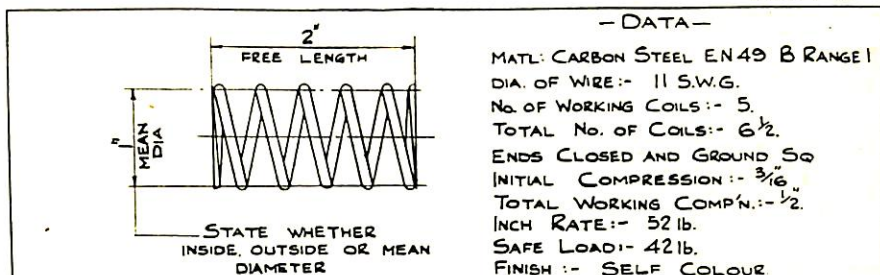
NOTES:

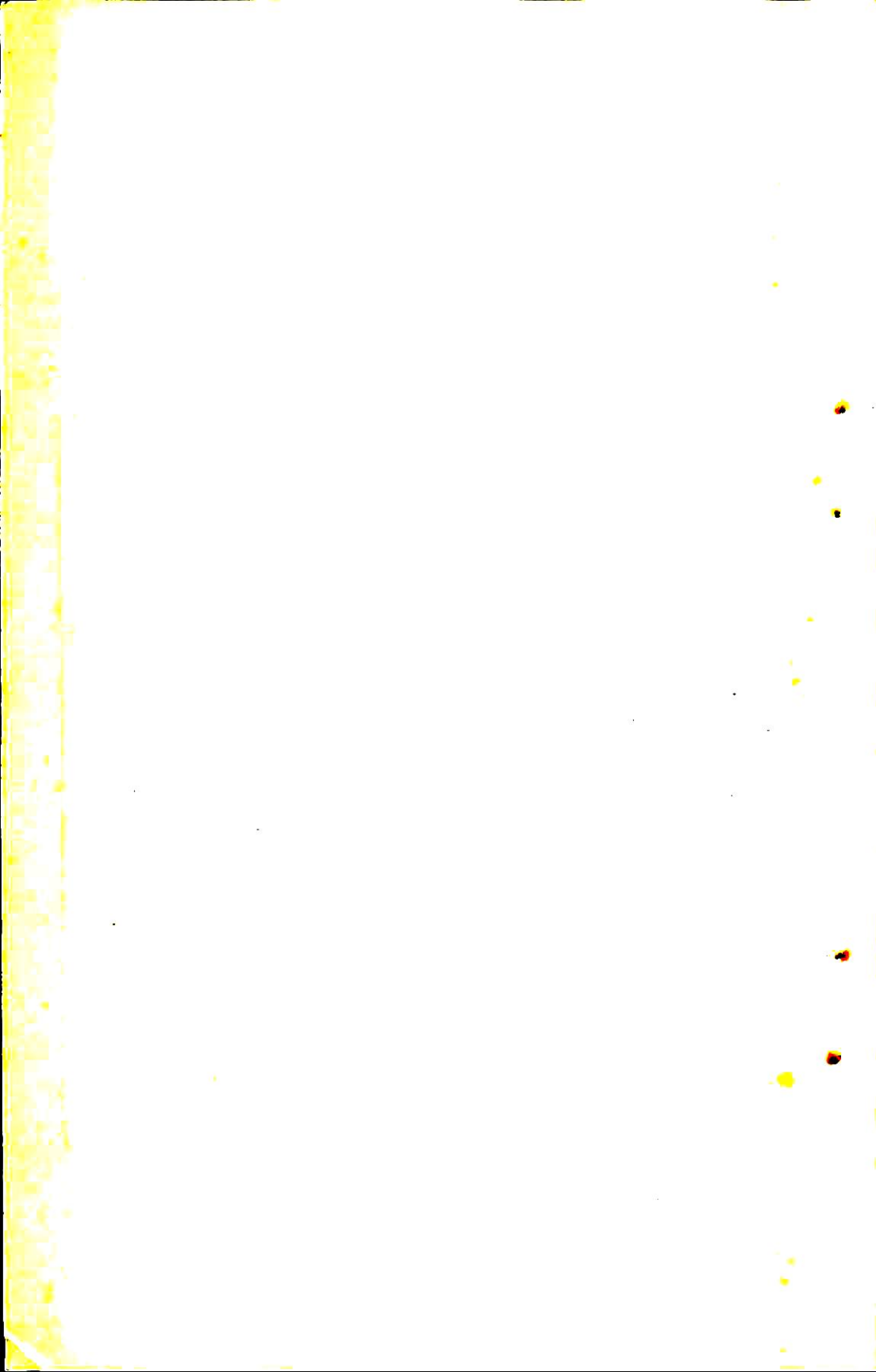
The Inch Rate Chart I is based on Formula 1 and compiled for Carbon Steel Wire and Chrome Vanadium wire where $G = 11.5 \times 10^6$. The figure given at the intersection of the wire dia. and the mean coil dia. must be divided by the number of working coils to give the Inch Rate. Allow $\frac{3}{4}$ coil extra each end for squaring off.

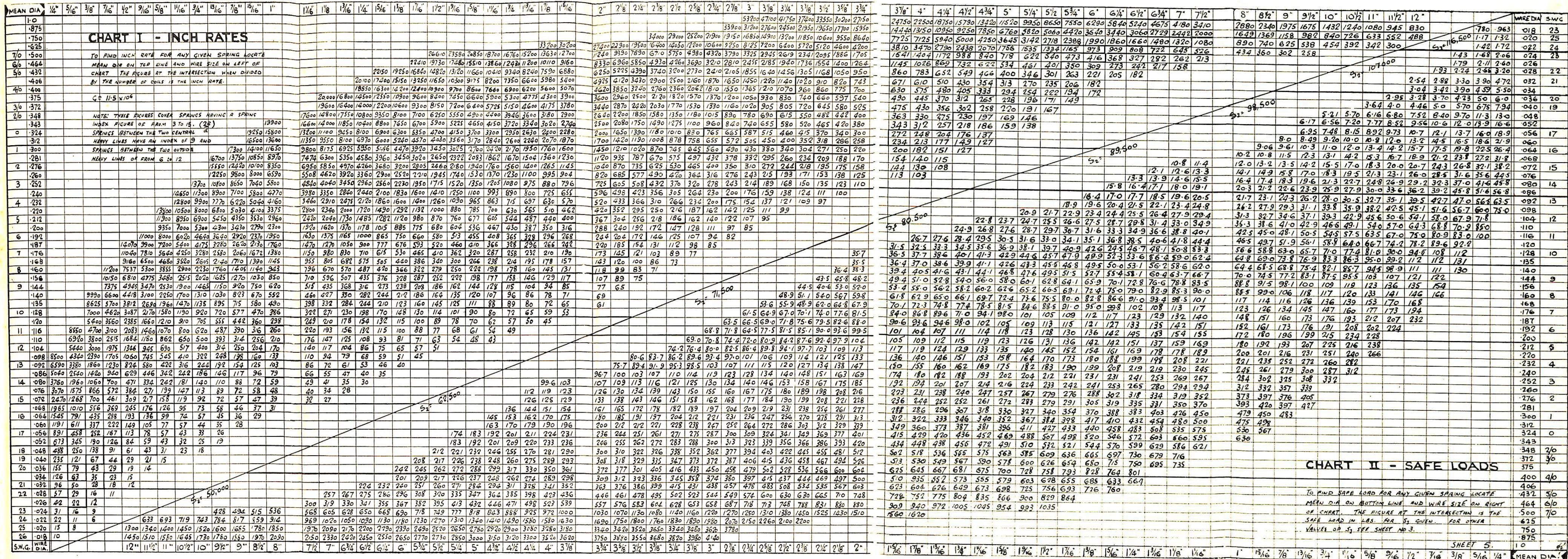
The Safe Load Chart II is based on formula 2 where S_2 = allowable safe stress for Hard Drawn Wire EN 49 B.C.+D to B.S. 1408/47. Range 1. To obtain Safe Load for Range 1 max. allowable stress or Ranges 2 & 3 min. or max. allowable stress multiply figure given by factor shown in Table below. The allowable safe stress is taken as 40% Ultimate Tensile Stress.

The Initial Load Chart III is based on formula 3 and applies to the Initial Tension Load on Extension Springs. This figure must be considered when finding the extension under load, but does not affect the Inch Rate. Square or Rectangular wire is hardened and tempered after coiling and has no initial tension.

TABLE OF SAFE STRESSES. Hard Drawn Wire EN 49 B.C.+D							
WIRE DIAS.	RANGE 1.		RANGE 2		RANGE 3.		
	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	
0.153 to 0.23	116,500	-	125,000	-	135,000	-	lbs/dia ²
	1		1.08		1.16		factor
0.24 to 0.34	107,000	116,500	116,500	125,000	125,000	135,000	lbs/dia ²
	1	1.08	1.08	1.17	1.17	1.25	factor
0.35 to 0.52	98,500	107,000	107,000	116,500	116,500	125,000	lbs/dia ²
	1	1.09	1.09	1.18	1.18	1.27	factor
0.53 to 0.86	89,500	98,500	98,500	107,500	107,500	116,500	lbs/dia ²
	1	1.1	1.1	1.2	1.2	1.3	factor
0.87 to 1.36	80,500	89,500	89,500	98,500	98,500	107,500	lbs/dia ²
	1	1.11	1.11	1.22	1.22	1.34	factor
1.37 to 2.02	71,500	80,500	80,500	89,500	89,500	98,500	lbs/dia ²
	1	1.13	1.13	1.25	1.25	1.38	factor
2.03 to 2.64	62,500	71,500	71,500	80,500	80,500	89,500	lbs/dia ²
	1	1.14	1.14	1.29	1.29	1.43	factor
2.65 to 4.00	62,500	-	62,500	71,500	71,500	80,500	lbs/dia ²
	1		1	1.14	1.14	1.29	factor







WIRE SIZE	MEAN DIA.	1/4"	5/16"	3/8"	7/16"	1/2"	9/16"	5/8"	3/4"	7/8"	1"	1 1/8"	1 1/4"	1 3/8"	1 1/2"	1 5/8"	1 3/4"	1 7/8"	2"	2 1/8"	2 1/4"	2 3/8"	2 1/2"	2 5/8"	2 3/4"	2 7/8"	3"	3 1/8"	3 1/4"	3 3/8"	3 1/2"	3 5/8"	3 3/4"
4	.240																																
5	.232																																
6	.220																																
7	.212																																
8	.200																																
9	.197																																
10	.187																																
11	.176																																
12	.168																																
13	.160																																
14	.156																																
15	.144																																
16	.140																																
17	.135																																
18	.128																																
19	.120																																
20	.116																																
21	.110																																
22	.104																																
23	.098																																
24	.092																																
25	.086																																
26	.080																																
27	.075																																
28	.070																																
29	.068																																
30	.064																																
31	.060																																
32	.056																																
33	.052																																
34	.048																																
35	.040																																
36	.036																																
37	.034																																
38	.032																																
39	.028																																
40	.026																																
41	.024																																
42	.022																																
43	.020																																
44	.018																																
45	.016																																
46	.015																																
47	.014																																

CHART III INITIAL TENSION LOADS (EXTENSION SPRINGS)

THE ABOVE TABLE GIVES THE INITIAL LOADING FOR TENSION SPRINGS AND SHOULD BE USED IN CONJUNCTION WITH INCH RATE CHART I. THE FIGURES GIVEN ABOVE SHOULD BE CONSIDERED WITH THE TOTAL LOAD ON THE SPRING AND DOES NOT AFFECT THE INCH RATE.

E.G. TENSION SPRING 13 SWG WIRE 1/2" M.D.I.A.
20 COILS RATE FROM CHART I = 41.2 lb
THEN LOAD TO EXTEND SPRING L INCHES =
L x 41.2 + 11 lb INITIAL LOAD FROM CHART III

